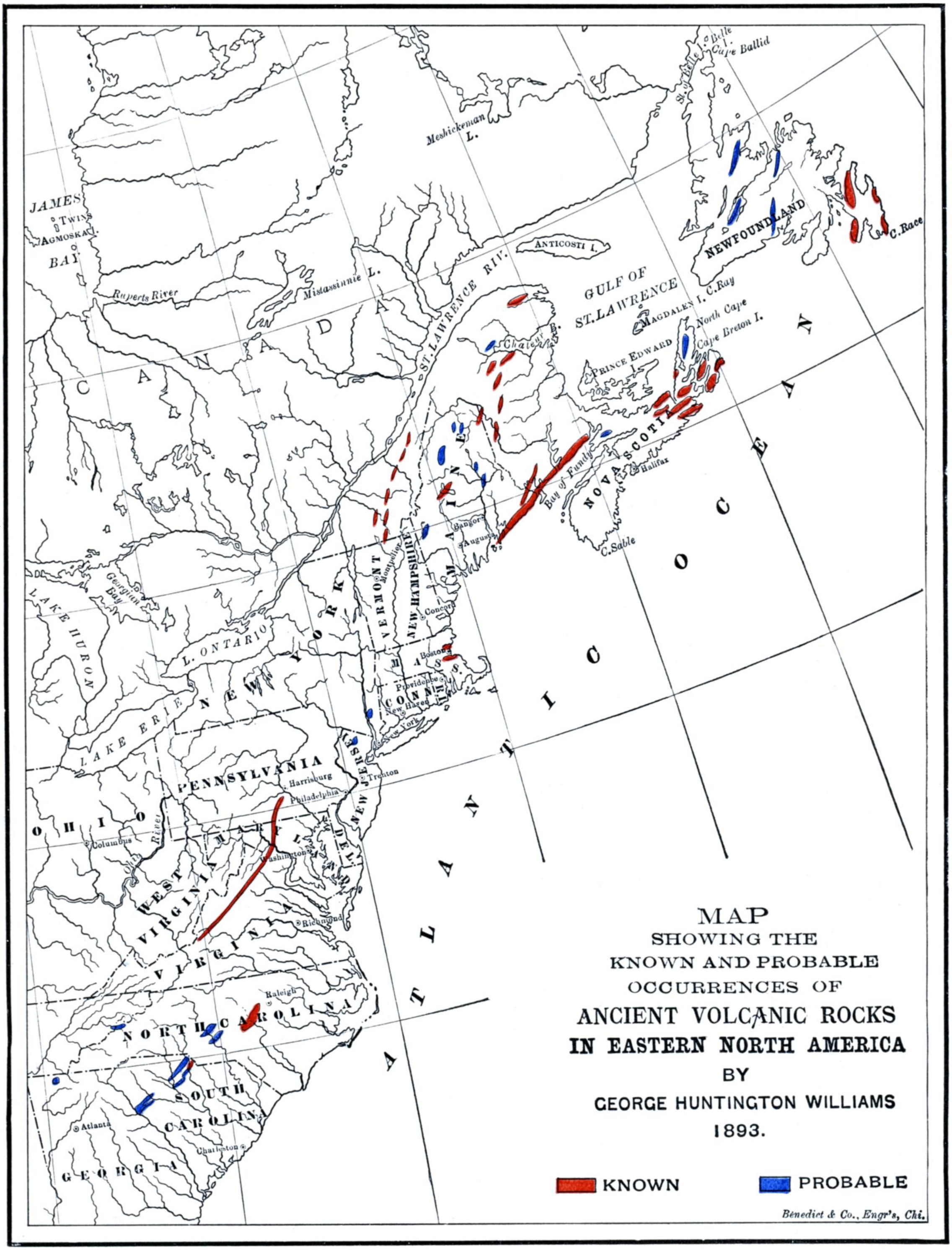
MAP
SHOWING THE
KNOWN AND PROBABLE
OCCURRENCES OF
ANCIENT VOLCANIC ROCKS
IN EASTERN NORTH AMERICA
BY
GEORGE HUNTINGTON WILLIAMS
1893.
KNOWN
PROBABLE
Benedict & Co., Engr's, Chi.
CANADA
ATLANTIC OCEAN
GULF OF ST. LAWRENCE
NEWFOUNDLAND
C. Race
ANTICOSTI I.
NOVA SCOTIA
Halifax
C. Sable
Bay of Fundy
PRINCE EDWARD I.
Cape Breton I.
North Cape
MAGDALEN I.
C. Ray
Cape Bauld
Belle I.
Meshickeman L.
Mistassinnie L.
Ruperts River
JAMES BAY
ST. LAWRENCE RIV.
Chaleur B.
MAINE
Bangor
Augusta
NEW HAMPSHIRE
Concord
VERMONT
Montpelier
MASS.
Boston
Providence
CONN.
New Haven
New York
NEW YORK
NEW JERSEY
Trenton
L. ONTARIO
LAKE ERIE
LAKE HURON
Georgian Bay
PENNSYLVANIA
Harrisburg
Philadelphia
MARYLAND
DEL.
Washington
OHIO
Columbus
Ohio River
WEST VIRGINIA
VIRGINIA
Richmond
NORTH CAROLINA
Raleigh
SOUTH CAROLINA
Charleston
GEORGIA
Atlanta

THE

JOURNAL OF GEOLOGY

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THE DISTRIBUTION OF ANCIENT VOLCANIC ROCKS ALONG THE EASTERN BORDER OF NORTH AMERICA.[1]

CONTENTS.

THE great crystalline belt of the Eastern United States and Canada, in spite of all the attention it has received, is probably still the least understood geological province of our continent. Here, almost more than anywhere else, personal adherence to some preconceived theory of the origin and relationships of rocks has biased observation and led to contradictory or unsatisfactory

[1] This paper was outlined at the International Geological Congress in Chicago, August, 1893, and read in full before the Geological Society of America at its Boston Meeting, December 28, 1893.

interpretations of the facts. Only within recent years has detailed and independent work been undertaken in widely separated parts of this vast area, and as yet no sufficient data is at hand for structural, or even for petrographical correlation throughout the whole.

Complete geological maps, showing the structural relations and chronological sequence of all the crystalline formations, are undoubtedly what must be looked forward to as the ultimate aim of work within this region, but the most sanguine will surely admit that we are at present a long way from any such reality. Meanwhile, in the absence of paleontological evidence, the study of the rocks from the point of view of genesis and the establishment of petrographic correlations will do much toward furnishing the positive basis of knowledge upon which final solution of complex structure must rest.

Some of the notions regarding petrographic sequence and the origin of foliation, enforced by masters of geology high in authority, have obscured rather than advanced the problems presented by the crystalline rocks in eastern North America. Not only have we been taught that the mineralogical and structural characters of these rocks are safe indices of their superposition and relative age, but the interpretation of all parallel structures as proofs of sedimentation has led to the conclusion that igneous rocks are rare, if not altogether absent, in these oldest and generally foliated formations of the earth's crust. Now, however, better conceptions are beginning to prevail. No longer do we regard the petrographic character of a crystalline rock as any criterion of its age, while modern methods have enabled us to identify the abundant igneous rocks of ancient times in spite of the misleading structures imparted to them by secondary causes.

Object of this paper.—The present writer has had frequent occasion to insist on the presence of such disguised igneous masses in the oldest geological formations, and to dwell upon the methods by which their origin may be established. In the present paper it is his object to show that not only igneous, but

also *volcanic*[1] rocks are widely distributed through the crystalline belt of eastern North America, and to direct attention to them as offering a new and promising field for work in crystalline geology. For the accomplishment of this purpose it will be necessary (1) to consider the general attitude of geologists in different countries toward ancient volcanic rocks; (2) to specify the criteria available for their identification; and (3) to summarize our present knowledge of where such rocks certainly or probably exist in the eastern crystalline belt. The material embraced under the third of these heads has been obtained from personal work in the field, from a careful study of existing literature, and from unpublished observations and hints furnished by friends.[2]

It is hoped that the bringing together of what is now known of the distribution of ancient volcanic rocks in eastèrn North America, with the addition of new areas and indication of localities where they may be looked for, will stimulate further work in widely separated portions of this interesting field. These rocks have, it is true, already been correctly described at a few isolated points, but no attempt has before been made to connect such areas or to show their probably widespread distribution. The recent identification by the writer of a very extensive development of pre-Cambrian lavas and volcanic tuffs and breccias in the South Mountain of southern Pennsylvania and Maryland[3]

[1] The term *volcanic* might perhaps be applied with propriety to all rocks produced in or on a volcano, without regard to their structure or coarseness of grain. It is, however, here employed only for effusive or surface igneous rocks, in contrast to such as have solidified beneath the surface, either as the basal portions of volcanoes, or as dykes, sheets, laccolites, or stocks (bathylites).

[2] The writer is especially indebted for help to Professor Eugene Smith, of Alabama; Professor W. S. Bayley, of Waterville, Me.; Professor J. A. Holmes, of North Carolina; Professor H. D. Campbell, of Lexington, Va.; Dr. A. C. R. Selwyn, of Ottawa; Mr. L. V. Pirsson, of New Haven; Professor S. L. Powell, of Newberry, South Carolina, and Mr. Arthur Keith, of Washington. The "Azoic System" of Whitney and Wadsworth, and Professor Van Hise's Correlation Essay on the Algonkian have also proved of much service.

[3] Am. Jour. of Science (3d ser.), Vol. 44, p. 495, Dec., 1892. These rocks have been thoroughly studied by Miss Florence Bascom, whose results may be expected soon to appear in full and adequately illustrated form. See also this Journal, Vol. 1, No. 8, Dec., 1893.

naturally suggested a comparison of these rocks with those of similar character in the Boston basin and eastern Canada, as well as a further search for other regions of the same kind. This search has already proved successful in North Carolina and Maine, while an examination of the older literature indicates many other places where a recurrence of like conditions may be confidently expected.

The proper interpretation and areal mapping of all the demonstrably volcanic regions in the Appalachian crystallines will not only afford much material of interest in the study of petrography and dynamometamorphism, but will also contribute to the differentiation and final understanding of the vast belt of diverse crystalline rocks to which they belong.

DIVERSITY OF OPINION REGARDING ANCIENT VOLCANIC ROCKS.

There is notable in the different countries where geology is cultivated a wide diversity of opinion regarding ancient volcanic rocks. In some regions such rocks have been entirely overlooked or else misinterpreted; in others they are recognized, but are conceived as having been formed under circumstances so different from those which now obtain that they are genetically and inherently distinct from the products of modern volcanoes; in a few only are they considered as having been originally identical with recent effusive rocks, and as differing from them only in alterations due to subsequent causes. This diversity of opinion may be accounted for in part by the varying state of preservation of ancient volcanic material in different parts of the earth's surface or by the lack of experience of field geologists with the characteristic features of modern lavas. It is, however, also due in a measure to the persistence of certain ideas promulgated by early masters of the science in their respective lands.

It was in Great Britain that the real nature of ancient volcanic products received its earliest and fullest recognition. In spite of the absence of active volcanoes from the islands, these rocks have from the earliest days of geological inquiry been favorite

subjects of investigation. From the first, their essential identity with modern volcanic products has been clearly recognized and repeatedly insisted upon—something which we may attribute to the doctrines of Hutton and to the uniformitarian principles of Lyell. Such geologists as Scrope, de la Beche, Sedgwick, Murchison, Jukes, Lyell and Ramsay, speak continually of lava-flows, tuffs, breccias and ash-beds in a way that implies no doubt in their minds as to the existence of volcanoes like those now active, in Paleozoic and pre-Paleozoic times. And more recently the delicate methods of modern petrography have in the same country been first made to establish the identity between ancient volcanic rocks and those of the present. The world is now but beginning to follow in this respect the lead set by Allport, J. A. Phillips, Judd, Bonney, Rutley, Harker, Cole and others in Great Britain. A few Englishmen, like Mallet or Hicks, have considered the oldest volcanic rocks either as originally different from those now produced, or as characteristic of some definite geological horizon, but, on the whole, the British school of geology, more than any other, recognizes a practical uniformity in the nature of volcanic action and products from the Archean to the present.[1]

In Germany and France volcanic rocks (*Ergussgesteine*) are recognized as abundant in certain of the earlier geological formations. Nevertheless there is in these countries a prevailing tendency to separate Tertiary from pre-Tertiary rocks of this class as things originally and genetically distinct.[2] It is noticeable that the earlier schemes of rock-classification, like those of Brongniart, Haüy, Cordier and K. C. von Leonhard, are quite purely mineralogical. The division of older and younger, or paleo- and neo-volcanic rocks is to be in part accounted for by the concentration of these masses in central Europe within the Permo-Carboniferous and Tertiary periods and their comparative

[1] See "The History of Volcanic Action in the Area of the British Isles," Presidential Address by Sir ARCHIBALD GEIKIE, F.R.S., etc. Quart. Jour. Geol. Soc., Vols. 47 and 48, 1891–2.

[2] ROTH: Sitzber. Berl. Ak. 1869, p. 72, *et seq.* ZIRKEL: Lehrbuch der Petrographie, 2d. ed., Vol. I., p. 838, 1893.

rarity in Mesozoic times. It is, however, also connected with the Wernerian doctrine of the non-recurrence of certain physical conditions in the earth's development, as contrasted with the uniformitarianism of Hutton and Lyell. The absence of volcanic types in Europe which serve to bridge over the sharp contrast between those of the Carboniferous and Tertiary, is being rapidly compensated by the discovery of such rocks in other regions. Fortunate finds of even pre-Cambrian lavas so perfectly preserved as to demonstrate their practical identity, both chemically and structurally, with recent products is tending to weaken the old distinction on the continent. There are now many signs of progress toward the idea that the characters regarded as belonging peculiarly to the older effusive rocks are better explained through changes subsequent to their solidification.

Thus Ludwig in 1861,[1] Vőgelsang in 1867,[2] and Lossen in 1869,[3] regard some quartz-porphyries as only devitrified glasses, identical with those of modern volcanic regions; Kalkowsky,[4] and recently Sauer[5] and Vogel,[6] have also brought convincing proof that such is often the case.

Gümbel says: "Es scheint in dieser Beziehung denn doch eher gerechtfertigt, zunächst das petrographisch Gleiche auch gleich zu bezeichnen, als in einzelnen Fällen ein neues Princip, das *des Alters,* in die Petrographie einzuführen, welches bei den meisten übrigen Fällen nicht verglichen und berücksicht werden kann;"[7]

And Rosenbusch also remarks:

"Man hat *den geologischen Alter* der Eruptivgesteine bisher ein höheres bestimmendes Moment für die structurelle und mineralogische Ausbildung dieser zugeschrieben als demselben in Wirklichkeit zukommt."[8]

[1] Erl. z. geol. Karte Hessens, Bl. Dieburg, p. 56, 1861.

[2] Philosophie der Geologie, pp. 144–146, 1867.

[3] Abh. Berl. Ak., 1869, p. 85.

[4] TSCHERMAK'S Min. Mitth, pp. 31 and 58, 1874.

[5] Erl. zur geol. Specialkarte Sachsens, Bl. Meissen, pp. 81–91, 1889

[6] Abh. geol. Landesanstalt von Hessen, vol. ii., p. 38, 1892.

[7] Grundzüge der Geologie, 1888, p. 85.

[8] Die massigen Gesteine, 2d. ed., 1887, p. 4.

He nevertheless adheres to the division between paleo- and neo-volcanic rocks, although he says that about their only difference is that the latter can often be found to belong to volcanoes (*i. e.*, volcanic mountains) which are themselves so extremely subject to removal by erosion.[1]

Admirable observations on the use of age in rock-classification are made by M. Neumayr. He says:

"Wohl muss der Geolog dem Alter der Gesteine Rechnung tragen, aber diese Berücksichtigung ist eine von der Beschreibung und Eintheilung der Gesteine durchaus unabhängige Sache. Wie schon oft betont worden ist, ist unter den Sedimentärgesteinen das richtige Prinzip schon durchgeführt, dass man von Kalken, von Dolomiten, Sandsteinen, etc., des Silur, des Jura, des Tertiär spricht, ohne die verschiedenalterigen Gesteine von gleicher Beschaffenheit mit eignen Namen zu belegen; genau in derselben Weise wird man auch mit den Massengesteinen verfahren müssen. Auf einen solchen Standpunkt wird und muss die Gesteinslehre ebenfalls gelangen; sie wird ihre Unterscheidung der Felsarten nur nach petrographischen Merkmalen und petrographischer Methode vornehmen, und die Altersbestimmung der Geologie überlassen, was natürlich nicht ausschliesst, dass beide Forschungsgebiete von einer und derselben Person beherrscht werden."[2]

In Belgium we see de la Vallée Poussin in 1885 writing of "Les anciennes Rhyolites dites Eurites,"[3] just as they would in England; while in France the recognized leader in petrographical usage, Michel-Lévy, although he still distinguishes "*roches porphyriques ante-tertiaires*," from "*roches trachytoides tertiaires et post-tertiaires*," expresses himself in regard to the futility of the age distinction in rock nomenclature as follows:

"On voit, par tout ce qui précède, qu'il est nécessaire d'asseoir une classification pétrographique rationnelle sur des faits contingents, indépendents d'hypothèses géogénétiques, et que la considération de l'âge des roches, à ce point de vue, est aussi hypothétique que celle de leurs conditions de gisement dans les profondeurs ou à la surface. Etant donné un échantillon de provenance inconnue, il est indispensible et il est possible de le nommer et de le décrire sans amphibologie. Il n'est possible d'en déterminer, avec certitude et précision ni le gisement ni l'âge géologique."[4]

[1] Ib., p. 6.

[2] Erdgeschichte, Vol. 1, p. 599.

[3] Bull. de l'Acad. roy. de Belgique (3) Vol. 10, No. 8, 1885.

[4] Structures et Classification des Roches Eruptives, p. 34, 1889.

In Scandinavia, if we judge from the most recent publications, there is, in spite of the general adherence to German nomenclature, a fuller recognition of the similarity between ancient and modern volcanic rocks than is to be found in any other part of Europe except England.

On the western coast of Norway, Reusch describes old lava flows of quartz-porphyry and more basic diabase amygdaloids which show spheroidal parting on a large scale due to cooling. These rocks are accompanied by tuffs and breccias which, in spite of subsequent dynamic action, still show their original characters. In one case, on the island of Gjeitung, occurs a deposit of pumice bombs cemented by what is now a chlorite schist.[1]

In Sweden Högbom describes the general distribution of post-Archean (Algonkian) eruptive rocks, many of which bear unmistakable evidence of volcanic character.[2] Otto Nordenskjold assigns the beautiful flow-porphyries and amygdaloids of the Elfdalen region to the same horizon, while he concludes that most of the Hälleflintas of southeastern Sweden (Småland) are surface lavas. He finds in them such well-developed fluidal, eutaxitic, rhyolitic and perlitic structures that they may be regarded as old rhyolites or devitrified obsidians.[3] The probably much younger and still glassy rhyolites of the gneiss area of Lake Mien are described by N. O. Holst.[4]

In Russia Tschernyschew describes from the central Urals many types of eruptive rocks, and among them both acid and basic volcanics of great antiquity, accompanied by their agglomerates, breccias and tuffs.[5]

In America the recognition of the true character and relationships of ancient volcanic rocks has been greatly retarded both

[1] Bömmelöen og Karmöen, pp. 109, 122, and 403, 1888.

[2] Geologiska Fören. i Stock. Förh., Vol. 15, p. 209, 1893.

[3] Bull. geol. Soc. Upsala, Vol. 1, Nos. 1 and 2, 1893.

[4] Afhandl. Sverig. geol. Undersök. Ser. C, No. 110, 1890.

[5] Allgemeine geologische Karte von Russland, Bl. 139, Central Urals. Text 4° pp. 323 and 333, 1889.

by the adherents to the so-called metamorphic school, like Dana, Logan, Rogers, Lesley and Winchell, who fail to find among the ancient foliated crystallines anything beside altered sediments, but perhaps even more by the influence of that most extreme of all Wernerians, Dr. T. Sterry Hunt. While antithetically opposed to the members of the metamorphic school in his notions of lithological character as an index of geological position, Dr. Hunt had in common with them the conviction that the ancient lavas and volcanic breccias, tuffs and ash-beds were normal aqueous deposits. The basic volcanics of eastern North America enter so argely into his "Huronian," and the acid types so largely into his "Arvonian," that his writings may still be used as suggestive of localities where ancient effusive rocks may be sought for.[1]

But there have not been wanting those among the earlier American geologists who have clearly recognized the igneous members of the ancient crystalline formations, in spite of their disguised character. Prominent among them are E. Hitchcock, Emmons, Lieber, Foster and Whitney. Not only the igneous, but the volcanic (surface) character of the Lake Superior lavas has been maintained by Pumpelly,[2] Wadsworth,[3] Irving,[4] Van Hise[5] and the present writer.[6] In Canada igneous rocks have always been regarded abundant in the oldest formations, while the volcanic character of some of them has been insisted on by Selwyn[7] and mentioned by other members of the Canadian Geological Survey. A looseness of usage is, however, observable in some of these reports, where "volcanic" is made synonymous

[1] See: Presidential Address, Am. Assn. Adv. Sci., 1871; Proc. Am. Assn. Adv. Sci., 1876, p. 211–211; Azoic Rocks, 1878; Am. Jour. Science, May, 1880; Mineral Physiology and Physiography, Chap. IX., 1886.

[2] Geology of Michigan, Vol. 1, 1873.

[3] Bull. Mus. Comp. Zoöl., Vol. 7, p. 111, 1880.

[4] Monograph V., U. S. Geological Survey, 1883.

[5] Bull. Geol. Soc. Am., Vol. 4, p. 435, 1893.

[6] Bull. U. S. Geol. Surv., No. 62, p. 192, *et seq.*, 1890.

[7] Report of the Geol. Survey of Canada for 1877–78. A, p. 5. Trans. Roy. Soc. of Canada, Vol. 1, p. 10, 1882.

with "igneous."[1] In the eastern United States Wadsworth was the first to declare for the volcanic origin of the felsites and tuffs in the Boston basin which, through the influence of Hunt's doctrine had, after Hitchcock's time, come to be explained as sediments. To Dr. Wadsworth also belongs the honor of having been the first geologist on this continent to insist on the original identity of these old lavas and pyroclastics with the recent volcanic rocks of the Cordilleras.[2] There is little doubt that the finely preserved ancient volcanic material in the eastern crystalline belt and elsewhere will, when it is adequately studied, finally bring to this opinion most American geologists. If we as yet know little of the extent and distribution of our ancient volcanics, we are at least bound by no traditions to artificial and useless age distinctions, and may freely follow the lead of our English colleagues.

CRITERIA FOR THE RECOGNITION OF ANCIENT VOLCANIC ROCKS.

It is a self-evident proposition that the identification of certain rocks as volcanic products is in no way dependent upon their present association with a recognizable crater or volcanic mountain. By volcanic rocks we understand igneous or pyroclastic material which has solidified or been deposited at, or very near the earth's surface. It is of little moment whether or not it was ever piled into conical mountains. That the rocks themselves bear witness to their origin and conditions of formation is sufficient. The successive effects of erosion on the easily removed volcanic mountains has been so often graphically described[3] that no further reference to the subject is here necessary. If the Eocene or Triassic volcanoes have so disappeared as to leave

[1] For instance, Ells in his "Geology of the Eastern Townships" (Can. Rept. for 1886, J.) speaks of pre-Cambrian rocks as "volcanic" and "plutonic," but enumerates only granite, diorite and serpentine.

[2] Bull. Mus. Comp. Zoöl., Vol. 5, 1879, p. 277 *et seq.*, and Azoic System, ib., Vol. 7, 1884, p. 429.

[3] See, DE LA BECHE: Geological Observer, pp. 526–537, 1851. M. NEUMAYR: Erdgeschichte, Vol. 1, pp. 202–204, 1887. W. M. DAVIS: "The Lost Volcanoes of Connecticut," Popular Science Monthly, Dec., 1891.

only traces of their original forms, what may we expect of those of Paleozoic or Archean times?

On the other hand, the association in dissected volcanic regions of the effusive rocks with correspondingly abyssal types naturally *suggests* that volcanoes may have once surmounted many areas of coarsely granular ancient igneous rocks. As this, however, cannot be proved, only such regions are here considered as yield rocks of unmistakably surface origin.

Again, ancient volcanic rocks may have been subjected to metamorphosing processes severe enough to have destroyed most of their original characters. In such cases, patient study and a careful weighing of all evidence is necessary to decide their origin, and even that may not avail. Igneous rocks may be so altered as to be indistinguishable from metamorphosed sediments, but it many cases where this at first appears to be the fact, some decisive clue may be discovered.

In establishing the volcanic nature of rocks occurring in ancient and more or less crystalline terrains, attention must be given to several different sets of characters. The field relations must be carefully studied and the material collected on the spot and afterward studied in the laboratory. The criteria for deciding on their igneous and volcanic origin may be arranged as follows:

I. If the rocks are *igneous*, whether abyssal or surface, they will:
   1. Conform in chemical composition to certain well established types;
   2. Show an association of petrographical types which, both chemically and mineralogically, follow the laws of consanguinity.

II. If they are *volcanic:*
   1. They may be found in the field to occur in distinct sheets, flows or necks;
   2. They will have produced very little or no contact action in the adjoining rocks;
   3. They may include irregular fragments of other rocks.

III. If they are *volcanic:*

1. They may appear to be striped, banded, or pseudo-"stratified" conformably to adjoining sedimentary deposits;
2. They will probably be accompanied by fragmental (pyroclastic) material, which may or may not itself be really stratified. Such material will vary greatly in coarseness, containing bombs, agglomerates, breccias, tuffs, sands and ashes. The characteristics of these are:
   1) indiscriminate mixture of all sizes and shapes of fragments;
   2) material of same kind as the igneous rocks;
   3) cement, either finer fragmental material (tuff-breccia) or lava (flow-breccia);
   4) very angular shape of smallest fragments (microscopic glass sherds).
   5) if ancient volcanoes were on the shore-line, such material may have been immediately worked over by water and interbedded with more or less normal aqueous sediments.

IV. Most important of all, however, is the identification of those characteristic structures known to originate only in glassy, half-glassy or very fine grained porphyritic rocks, solidifying at the surface, or in very narrow dykes where solidification has been rapid. These will be found to be very persistent and can usually be identified under the microscope in spite of devitrification, alteration, or even a considerable degree of dynamometamorphism. The most common of these structures are:

1. a vesicular, scoriaceous, pumiceous or amygdaloidal structure;
2. a sharply defined, small porphyritic structure with a glassy, half-glassy or felsitic (cryptocrystalline) base;
3. a spherulitic structure, due to either large or small lithopysæ, hollow spherulites, or compact spherulites,

arranged either irregularly, or in more or less discontinuous bands or layers;

4. a flow structure, produced either by the elongation of vesicles or the parallel arrangement of constituents or crystallites. It may also be produced by the interlacing of different colored magmas (eutaxitic structure);
5. corroded phenocrysts, quartz with embayments, or skeleton crystals due to rapid and imperfect growth;
6. microscopic spherulites, globulites, trichites, crystallites, real or devitrified glass inclusions, quartz with orientated siliceous aureoles, axiolites, etc.;
7. perlitic structure, wholly or partly devitrified.

Although some of these structures may occasionally occur in dykes or other igneous rocks which have rapidly solidified beneath the surface, they are nevertheless so essentially characteristic of effusive lavas, that, in lack of any evidence to the contrary, they may be regarded as fairly safe guides in establishing the effusive nature of rocks. This evidence is beyond doubt, if such rocks are accompanied, as they generally are, by ash material.

While a single one of these characteristics may not be sufficient to identify a volcanic occurrence, many, if not all of them, will be found to occur together, and only in rare instances will it be found that some of them, at least, have not survived the vicissitudes of metamorphism. That many regions in the ancient crystalline belt of the Appalachian system exhibit most of them in great perfection is now well known. It is only a misinterpretation of these characteristic features of volcanic rocks, due to a lack of acquaintance on the part of observers with their recent analogues, that has prevented their recognition long ago. Thus, by those who have heretofore described these rocks as sediments, both secondary cleavage, and the banding due to flow or parallel spherulitic layers have been mistaken for stratification; spherulites have been erroneously regarded as concretions; and the accompanying pyroclastics, as normal conglomerates or slates.

It is the purpose of the writer in the present paper to maintain that *in the great crystalline belt of eastern North America, large areas of volcanic rocks occur, and that these, in spite of their great age, are in all respects the same as modern volcanic materials, save for alterations subsequent to their original formation—among which alterations devitrification has been one of the most important.*[1]

DISTRIBUTION OF VOLCANIC AREAS ALONG EASTERN NORTH AMERICA.

I shall now proceed to summarize the present state of our knowledge of these volcanic areas, as far as they belong to the Eastern or Appalachian crystalline belt, omitting all reference to the central Canadian, Lake Superior, Missouri, or other more western regions of similar nature. In this review I shall commence with Newfoundland and follow them southwest, parallel to the coast.

Eastern Canada.—In a recent comparison between the Eozoic and Paleozoic rocks of eastern America and western Europe, Sir William Dawson says that the Huronian was evidently a coarse marginal deposit, accompanied by abundant volcanic outbreaks, similar to those which occurred about the same time in Wales. He is also confident that many of the bedded Huronian rocks are really of volcanic origin, being ashes in an altered state.[2] In the same paper he mentions volcanic rocks, both lavas and pyroclastics, as abundant in the Ordivician and Silurian formations of eastern Canada.

The reports of the Canadian and Newfoundland surveys abound in references to rocks of a volcanic character in the early Paleozoic and pre-Paleozoic horizons. These references are, however, always purely those of a field-geologist engaged in a rapid reconnaissance. The frequent use of such field terms as felsite, porphyry, trap, amygdaloid, agglomerate, breccia and ash suggest a vast development of contemporaneous volcanic

[1] On the nomenclature of these ancient and devitrified lavas, see Miss FLORENCE BASCOM's paper, this Journal, Vol. I., No. 8, p. 825, Nov.-Dec. 1893.

[2] Quart. Jour. Geol. Soc., Vol. 44, p. 801, 1888.

materials, but thus far no petrographer has attempted to study systematically either the field or microscopical relations of any area of these interesting rocks. A very broad and interesting field is thus seen to be awaiting investigation in Newfoundland, Gaspé, New Brunswick, Nova Scotia and the Eastern Townships.

Professor J. B. Jukes, in his "Geology of Newfoundland," describes old lava flows and accompanying pyroclastic deposits as very abundant, especially on the peninsula of Avalon, which forms the eastern part of the island.[1] His observations are confirmed by the later reports of Murray and Howley, who agree that the western part of this peninsula was the scene of extraordinary volcanic activity in very early times.[2]

In his three reports on the eastern portion of Cape Breton, Fletcher describes the Ste. Anne, Boisdale, Coxheath, East Bay and Mira Hills, as composed largely of ancient (pre-Cambrian) volcanic rocks, among which felsites of all colors, felsite-porphyries, felsite breccias and amygdaloids abound.[3] Similar rocks appear also to extend up into, and to form an important part of the Cambrian, Silurian and Devonian formations. In a later report on the northern part of Cape Breton, Fletcher[4] finds that the greater part of the northern peninsula is also composed of "felsites," but the petrographical distinctions of both Fletcher and Gilpin[5] are so indefinite that a variety of coarsely crystalline rocks seem to be embraced in this general designation. In describing the Mira "felsites," Fletcher mentions those of Blue Mountain and Gull Cape, near Louisburg, as being "globular," or "concretionary," (coarsely spherulitic?) often presenting "single or united spheroids, the concentric layers of which may

[1] Excursions in and about Newfoundland in 1839 and 1840, 2 vols., 1843. Geology, Vol. 2, pp. 245–341.

[2] Reports of the Geological Survey of Newfoundland for 1868–1881.

[3] Reports of the Geol. Survey of Canada, 1875–76, pp. 369–418; ib., 1876–77, pp. 402–456; ib. 1877–78, pp. 1–32, F.

[4] Ib., 1882–83–84, pp. 1–98 H.

[5] Quart. Jour. Geol. Soc., Vol. 42, p. 515, 1886.

be removed like the coats of an onion." He also speaks of them as "coarsely brecciated" and "vesicular." A point of some interest is Fletcher's conclusion that "both felsite and syenitic strata are intimately associated as part of the same group of crystalline rocks, differing, not so much in composition as in the degree of crystallization they have been subjected to" (*sic*).[1] In greatly eroded regions we should expect to find surface volcanic rocks associated with their coarser abyssal equivalents.

In Nova Scotia proper the best known area of ancient volcanic rocks is in the northeastern corner of the province, near Arisaig, in Antigonish county. These were considered by Sir William Dawson in 1850 as "metamorphic."[2] In 1864, Dr. Honeyman described them as vesicular traps, amygdaloids and porphyries, associated with tufa and tufaceous conglomerate.[3] In his first report on eastern Nova Scotia, Fletcher describes variegated, vesicular and amygdaloidal "felsites" and "fragmentary felsites," like those of Coxheath and Louisburg, associated with "syenite" (hornblende granite) and diorite.[4] These rocks are regarded as pre-Cambrian, and are particularly developed at Arichat, Cape Porcupine on the Straits of Canso, and in the Sporting, North and Craignish mountains. In the North Mountains the felsites are said to pass gradually into syenite (l. c. p. 14). The gradual blending of the felsite and overlying George River limestone is attributed to "common metamorphism," rather than "to contemporaneous volcanic origin or subsequent intrusion" (l. c. p. 17). Nevertheless, at Cape Porcupine the felsite is regarded as possibly an igneous rock, since "the apparent lines of bedding are like those of a furnace slag" (l. c. p. 25). In the subsequent report of the extension of his explorations southward and westward in Nova Scotia, Fletcher admits the volcanic origin of the felsitic rocks of Arisaig, Doc-

[1] Quoted by GILPIN: Quart. Jour. Geol. Soc., Vol. 42, p. 516.

[2] Quart. Jour. Geol. Soc., Vol. 6, p. 347, 1850.

[3] Ib., Vol. 20, p. 333, 1864.

[4] Report of the Geol. Survey of Canada, 1879–80, F.

tor's Brook, Georgeville, Blue Mountain and East River of St. Mary's. These are quite like the Cape Breton and Cape Porcupine rocks, and carry copper, as they do in South Mountain, Pa., and on Lake Superior. He gives the age of these eruptions as probably pre-Cambrian, although at Arisaig they may be of any age older than Medina. Similar volcanic eruptions occur in all strata up to the base of the Carboniferous.[1] In his last report covering Pictou and Colchester counties, the same author describes Cambro-Silurian porphyries, agglomerates, fragmental felsites, breccias and amygdaloids from Moose and Sutherland rivers. A dyke-like mass of volcanic breccia occurs on Sam Cameron's brook. Similar volcanic products are also very apparent in the Devonian of these two counties, among the most interesting of which are the syenitic granites overlaid by thick volcanic deposits at the east end of the Cobequid Hills, as described by Dawson.[2] The well-known traps of northwestern Nova Scotia, along the Bay of Fundy, which furnish the beautiful zeolites and other minerals, are of Triassic age.

In New Brunswick and the Gaspé Peninsula, old volcanic rocks, like those of Newfoundland and Nova Scotia, are extensively developed. Ells and Low mention amygdaloidal traps and porphyries cutting various strata of Gaspé, up to and including the Devonian.[3] Felsitic rocks, similar to those which are better known further to the south, are rather vaguely mentioned by Robb in northern New Brunswick.[4] Ells, in his report on the same region in 1879–80, clearly describes as volcanic both acid and basic rocks. A vast area of felsite, petrosilex, porphyry and breccia, like that near St. Johns, is developed in the upper Nipisiguet river and lake Nictor. Another like it extends from the upper Upsalquitch river along Jacket river to the bay of Chaleur, while great masses of basic volcanics (amyg-

[1] Ib., 1886, P.

[2] Acadian Geology, 1878, suppl., p. 79.
Report of the Geol. Survey of Canada, new ser., Vol. 5, 1890–91, P. pp. 147–166.

[3] Ib., 1882–83–84, E. and F.

[4] Ib., 1870–71, p. 245.

daloids, aphanites, etc.) occur around the head of the Bay of Chaleur and Dalhousie, as well as on the upper Upsalquitch and Elm Tree rivers. Many of these rocks are pre-Cambrian, while others cut the Silurian strata.[1] Great sheets of contemporaneous trap are also found by Ells in the Silurian, and to a very small extent in the Devonian, along the north shore of the Bay of Chaleur. Bailey explored parts of northern and western New Brunswick, especially in Carolton, York and Victoria counties, and found porphyries, felsites and amygdaloids, intrusive in the Silurian and older formations in Canterbury, Woodstock and Kent townships, near the St. Johns river.[2] Still later Bailey and McInnes continued similar explorations, and found signs of intense volcanic action in the Niagara limestone at Pointe aux Trembles, and a great development of acid and basic surface rocks near the Aroostook river and at Presqu'ile and Haystack mountain in Maine.[3] The same is true near Tobique lake, farther to the northeast.

As early as 1839, Gesner describes the volcanic rocks along the Bay of Fundy, in southern New Brunswick, as belonging to several distinct horizons.[4] In 1865, Bailey, Matthew and Hartt distinguished two groups mainly of volcanic origin, to one of which, the "Coldbrook," they assigned a Huronian, and to the other, the "Bloomsbury," a Devonian age.[5] In 1872, Bailey and Matthew, after a season's field-work with Dr. T. Sterry Hunt, united the Coldbrook and Bloomsbury groups on purely lithological grounds, and for the same reason joined with them two other volcanic series—the Coastal and Kingston groups—exposed at other localities in southern New Brunswick.[6] The petrographical characters of these rocks were those regarded by Hunt as sufficient demonstration of Huronian age. The acceptance of this fallacious principle exercised a distinctly

[1] Ib., 1879–80, pp. 35 to 42.

[2] Ib., 2882–83–84, G. pp. 15 and 20; ib., 1885, G. pp. 22 and 28.

[3] Ib., 1886, N. pp. 14–15; and ib., 1887–88, M. pp. 32 and 47.

[4] First Report on the Geological Survey of the Province of New Brunswick, by ABRAHAM GESNER. 87 pp. 1839.

[5] Observations on the Geology of Southern New Brunswick. 1865.

[6] Report of the Geol. Survey of Canada, 1870–71, pp. 57–133.

retarding effect on the deciphering of New Brunswick geology. Numerous occurrences of felsite, porphyries and amygdaloids were described between Musquosh Harbor and Loch Lomond, near the city of St. Johns, and along the line between Kings and Queens counties (Coldbrook and Bloomsbury groups). Similar rocks were traced from L'Etang Harbor, near Passamaquoddy Bay, along the edge of the Bay of Fundy to Shepody, in Albert County (Coastal group); and finally, a belt of analogous composition was described between the Long Reach of the St. Johns river and Mace's bay (Kingston group). These rocks were at this time, however, on account of Hunt's influence, united with their associated sediments, and nothing is said about their volcanic character. These authors were forced to regard similar rocks on the shores of Passamaquoddy bay as Silurian, because of associated fossils, in spite of their lithological identity with the "Huronian." These they called the Mascarene series.[1]

Four years later the same authors united the Kingston and Mascarene groups and regarded both as upper Silurian.[2] In a report of the pre-Silurian rocks of Albert, eastern Kings, and St. Johns counties, Ells gives some clear statements relative to the volcanic rocks of southern New Brunswick. He says:

> "In their lithological aspect, the rocks forming the southern metamorphic belt present great diversity. Their general character is of two kinds—altered sedimentary and volcanic. * * * In the latter we include the great mass of petrosiliceous rocks, so called, with breccias and other ash rocks, which in places show bedding, but this is often so obscurely marked as to be exceedingly doubtful. * * * Near the contact of the volcanic and sedimentary rocks we find an extraordinary development of generally coarsely crystalline diorites and syenites, which would seem to form the basal portion of the volcanic part of the series."[3]

A report on the same rocks was published at the same time by Bailey, who divides them into a feldspathic, syenetic and gneissic group, including limestones, serpentines, and dolomites

[1] Ib., pp. 144–158.

[2] Ib., 1874–75, pp. 85–89.

[3] Ib., 1877–78, D. p. 3.

(Laurentian); a felsite-petrosilex group (Lower Huronian or Coldbrook); and a schistose, chloritic micaceous group (Upper Huronian or Coastal).[1] The results of all their work on the rocks of southern New Brunswick is summarized by Bailey, Matthew and Ells, with a general geological map in three sheets.[2]

That portion of the Province of Quebec lying south and east of the St. Lawrence is called the Eastern Townships. We have already considered that portion of it composing the Gaspé peninsula. The portion lying west of Maine and north of New Hampshire and Vermont was supposed by Logan to be wholly occupied by rocks of the Quebec Group. In 1879, Dr. Selwyn divided the rocks of this zone into three groups, which he defined as lower Silurian; volcanic (probably lower Cambrian); and crystalline (probably Huronian). The lower of these divisions forms an anticlinal axis extending from Lake Memphremagog to L'Islet County, 150 miles. It contains a great variety of altered sedimentary beds, associated with "diorites, dolerites, serpentines, amygdaloids, and volcanic agglomerates," regarded by Hunt as altered sedimentaries. The second division, said to be intimately related to the last, is largely composed

"especially on the southeastern side of the axis, of altered volcanic products both intrusive and interstratified, the latter being clearly of contemporaneous origin with the associated sandstones and slates."

These rocks are designated as

"dioritic, epidotic, and serpentinous breccias and agglomerates; diorites, dolerites and amygdaloids holding copper ore; serpentines, felsites and some fine grained granitic and gneissic rocks."

They are especially developed along the contact of the last-mentioned group, of which they "may be merely the upward extension."[3] In a later paper on the Quebec Group, Dr. Selwyn considers these volcanic rocks thoroughly from the English point of view. He says:

[1] Ib., DD. p. 2.

[2] Ib., 1878–79, D. p. 26.

[3] Ib., 1877–78, A. pp. 5–9.

"I would also submit that neither a schistose nor a bedded structure can be accepted as proof of a non-igneous or volcanic origin, and that a once massive lava-flow, whether augitic or feldspathic, is as likely, through pressure and metamorphism, to assume a schistose structure as are ordinary sedimentary strata. It is, I am aware, not in accordance with generally received ideas on the nature of ancient igneous rocks to suppose they can be schistose and stratified, especially so in America, where volcanic agency in the earlier geological periods has been almost entirely ignored, and all those rocks which by their microscopic characters and chemical composition, and by their geological associations and relations, point to volcanic agency as the cause of their formation, have been said to be '*not igneous, but metamorphic in origin*,' a description which, it seems to me, is decidedly self-contradictory." [1]

Selwyn later again maintained his volcanic group, and published microscopic descriptions of some of its rocks (quartz-porphyry and porphyrite) by Adams.[2] Little or nothing is added to our knowledge of the strictly volcanic rocks by the two subsequent reports on the geology of the Eastern Townships by Ells.[3]

The recognition of ancient volcanic rocks in the United States is far behind that which prevails in Canada. This, as has already been pointed out, is due to the influence of so-called "metamorphic" ideas, or more properly to the Wernerian doctrine, that every rock showing any foliated or parallel structure is sedimentary.

New England.—Very little definite information can be gathered from the earlier reports on the geology of Maine, by Jackson and C. H. Hitchcock, regarding the old volcanic deposits. Jackson frequently uses such petrographical terms as "amygdaloidal trap, ribbon jasper, clinkstone porphyry, and breccia composed of an infinity of fragments of jasper," in describing the rocks near Eastport and Machiasport, on the Maine coast. He regarded the basic rocks (trap) as eruptive, but the "jasper" as semifused sediments whose lines of stratification were still pre-

[1] Trans. Roy. Soc. Canada, Vol. I, p. 10, 1882.

[2] Report of the Geol. Survey of Canada, 1880–82, A. p. 2 and pp. 10–14.

[3] Ib., 1886, J., and ib., 1887–88, K.

served.[1] His descriptions are, however, very suggestive, especially in light of the truly volcanic rocks which have been recently discovered in the older strata of Maine. C. H. Hitchcock, in his Maine reports, regards the acid volcanic rocks near Machiasport as altered slates, and mentions extensive areas of similar rocks on Moosehead, Portage, Long, and Chamberlain lakes, as well as along the Aroostook and Penobscot rivers, in the interior of the state.[2] Goodale gives four patches of analogous "siliceous slates" in York county, and five in Oxford county, and J. H. Huntington describes the summit of the diorite southeast of Kennebago lake, in western Maine, as composed of compact felsite, which he regards as an eruptive rock.[3] The first definite descriptions of ancient volcanic rocks in Maine was given by Professor Shaler, who examined the regions about Eastport and Mount Desert. Near Eastport, and especially on McMaster's island, three types of volcanic material are largely developed: 1) detrital accumulations which have fallen through the air; 2) true lava flows; 3) dykes. They seem to belong to various horizons of Silurian age.[4] A similar series of interstratified volcanic breccias, lava flows and ash beds are described as forming a large part of Mt. Desert island south of Southwest Harbor, and the Cranberry Isles.[5]

The writer has had the opportunity to personally examine the volcanic rocks of the Mt. Desert region, and he is indebted to Professor W. S. Bayley of Waterville, Me., for specimens and slides of the beautiful lavas of Vinal Haven, and to Mr. E. B. Mathews for notes and specimens of similar rocks from Mt. Kineo on Moosehead Lake.

Along the shores of Cranberry Island occur hard jaspery felsites, often porphyritic, and exhibiting such characteristic features of glassy rocks as spherulites, single and in bands, flow-

[1] First Report on the Geology of the State of Maine, 1837, p. 12 and pp. 36–42.

[2] Geological Report, 1861, p. 190, and p. 432; also ib., 1863. p. 330.

[3] Proc. Am. Assn. Adv. Sci., Vol. 26, p. 286, 1877.

[4] Am. Jour. of Science (3d ser.), Vol. 32, pp. 40–43, 1886.

[5] Eighth Ann. Report U. S. Geol. Survey, pp. 1037, 1043, 1054. 1889.

structure, etc., in great perfection, although all trace of the original glass has long since disappeared. The rocks collected by Professor Bayley on the north side of Vinal Haven and on the opposite shore west of North Haven are, according to his field observations, all surface flows or tuffs. Of the nine specimens kindly submitted to me for examination by Professor Bayley, one is a medium grained microgranite and all the others

FIG. I.

FIG. I. Devitrified glass-breccia from north side of Vinal Haven, Penobscot Bay, Me. Magnified six times.

are devitrified glassy rocks, which were once either obsidians, glass breccias, or tuffs. No. 94 is a banded flow-felsite, a devitrified glass with narrow chains of spherulites. No. 100 is a devitrified obsidian containing delicate flow-lines produced by trichites, some zircon crystals, and spherulitic bands in which epidote has been secondarily produced. No. 126 is a pale gray felsite containing large round nodules which may be spherulites. Under the microscope it shows a pronounced perlitic structure. These rocks contain spherulitic structures which are not devitrification products but original, if we may judge from their absolute identity with similar structures in the glassy rocks from Obsidian Cliff. The other five specimens are fine grained vol-

canic ashes, most of them composed of very sharply angular fragments of devitrified glass or pumice with beautiful flow structures. The delicate detail produced by trichites in one of these is rather roughly represented in Fig. 1. It is not unlike the devitrified glass-breccia described by the writer from Onaping river in the Sudbury district.[1]

The specimens collected by Mr. Mathews at Mount Kineo on Moosehead Lake, and kindly loaned me for examination, are typical quartz-porphyries or keratophyres, some of which exhibit such perfect and delicate flow-lines that they can be regarded only as devitrified glassy lavas.

In New Hampshire felsites and quartz-porphyries abound. They were regarded as eruptive by Hitchcock and by Hawes when they occur in dykes, although the latter regarded many of them, especially when interstratified, as sediments fused *in situ*.[2] There are as yet no published descriptions which make it reasonably certain that truly volcanic, as contrasted with abyssal igneous rocks, occur within this state.

The important development of ancient volcanic rocks in eastern Massachusetts, in the neighborhood of Boston, has been more discussed than any other similar region on this continent. An excellent résumé of the development of opinion regarding these rocks has been given by Whitney and Wadsworth.[3] E. Hitchcock held correct views as to the igneous character of all the massive rocks, although he regarded the amygdaloids and some of the apparently stratified felsites as altered sediments. Later the influence of Hunt created a general impression that the greater part of these rocks—even the granites—were of sedimentary origin. Wadsworth was the first to successfully combat this idea, and to show that not only were the coarsest massive rocks igneous masses, but even the finer jaspery felsites and their

[1] Bull. Geol. Soc. Am., Vol. 2, p. 138, 1891.
Report of the Geol. Survey of Canada, 1890–91, F. p. 75.

[2] See Geology of New Hampshire, Vol. 2, p. 260, and Vol. 3, part IV., Mineralogy and Lithology, p. 171, 1878.

[3] The Azoic System, pp. 398–440, 1884.

accompanying fragmental materials were the products of ancient volcanic action. He maintained that the felsites of Marble Head were merely altered rhyolites which had once been quite like those of the western Cordilleras ; and their banding was flow-structure ; and that they were accompanied by ash beds which he called *porodites*.[1] Two years later the detailed work of Diller and Benton established the volcanic character of the felsites of Medford, Melrose, Malden, Sangus, Wakefield and Lynn, and of the amygdaloid of Brighton.[2]

Other areas of similar rocks occur near Newburyport, and also to the south of Boston at Needham, Dedham, Milton, Blue Hill, Hingham, Nantasket and Manomet,[3] but these have not as yet been so carefully examined as those farther north, although Crosby, in his recent " Geology of Hingham," classes the melaphyre. porphyrite, and felsite of Nantasket and Hingham as effusive or volcanic rocks, and describes the latter as "undoubtedly an ancient, devitrified obsidian."[4]

The Middle Atlantic States.—In New York state there are, as far as the writer is aware, no remains of igneous rock which have solidified at the surface. Nevertheless, the isolated and

[1] The Classification of Rocks. Bull. Mus. Comp. Zoöl., Harvard Coll., Vol. 5, p. 282, 1879. It is worthy of note, in view of all the erroneous ideas that have prevailed regarding the Boston felsites, that as early as 1822, Dr. Thomas Cooper, President of the College of South Carolina, in an article on "Volcanoes and Volcanic Substances" says : " No person accustomed to volcanic specimens can look at the porphyries from the neighborhood of Boston, in my possession, and doubt of their volcanic origin." (Am. Jour. of Science, 1st ser., Vol. 4, p. 239).

[2] "The Felsites and Their Associated Rocks North of Boston," by J. S. DILLER, Bull. Mus. Comp. Zoöl., Vol. VII., p. 165, 1881 ; and "The Amygdaloidal Melaphyre of Brighton, Mass.," by E. R. BENTON, Ph.D., Proc. Bost. Soc. Nat. Hist., Vol. 20, pp. 416–426, 1880. The writer is indebted to Mr. Diller for the privilege of examining his collection of slides of the Boston rocks which are in all essential respects identical with those from the coast of Maine, from South Mountain and North Carolina.

[3] E. HITCHCOCK : Final Report on the Geology of Massachusetts, Vol. 1, p. 150, 1841 ; W. O. CROSBY : Geology of Eastern Massachusetts, pp. 79–95, 1880.

[4] Proc. Bost. Soc. Nat. Hist., Vol. 25, p. 502, 1892. See also by the same author : The Lowell Free Lectures on the Physical History of the Boston Basin, 1889 ; and the Geology of the Boston Basin, Vol. 1, Part 1. Occasional Papers of the Boston Soc. Nat. Hist., IV., 1893.

highly differentiated "Cortlandt Series," near Peekskill, presents us with the deeply eroded roots of an ancient volcano, probably of Cambrian or Silurian age, whose superficial parts have entirely disappeared.[1] The eleolite-syenite area in northern New Jersey is probably of the same character.

In Pennsylvania and Maryland we find in the South Mountain or Blue Ridge, between Harrisburg and the Potomac, one of the most highly diversified and perfectly preserved areas of pre-Cambrian volcanic rocks in the world. Its position is established as below the Olenellus sandstone; it presents both acid (rhyolitic) and basic (basaltic) types; it exhibits within limited shear-zones the plainest effects of dynamic action, but its great mass is nevertheless so little changed that each microscopic structure of glassy rocks is clearly recognizable. Skeleton crystals, minute pores and larger vesicles, protoclastic breaking of the phenocrysts, fluidal structures of every kind, trichites, spherulites, axiolites, lithophysal and perlitic parting have lost none of their original sharpness, in spite of the complete devitrification of the glassy base. Most of the rocks were probably always wholly or mostly crystalline, but some regions, like the Bigham Copper and Raccoon Creek, display the old spherulitic obsidians and pumice in a manner allowing of no doubt. The pyroclastic materials accompanying these old lavas are also finely developed—ash-beds, coarse and fine flow- and tuff-breccias, etc. The precise centers of eruption within this region have not yet been definitely located, but with what has already been published regarding these rocks and the further details which may be soon expected, no further description of them is here necessary.[2] The entire misunderstanding of these rocks by Rogers, Hunt, Lesley and Fraser, who interpreted them as altered slates and their secondary cleavage as bedding, has greatly retarded the solution

[1] PROFESSOR DANA once suggested that the Cortlandt massive rocks might have been formed by the metamorphism of "volcanic debris or cinders" (Am. Jour. of Science, 3d ser., Vol. 22, p. 112, Aug. 1881), but he subsequently admitted their intrusive character (ib. Vol. 28, p. 384, Nov. 1884). See also opinions of the present writer (ib. Vol. 36, p. 268, Oct. 1888).

[2] Am. Jour. of Science (3rd ser.) Vol. 44, December, 1892, and Vol. 46, July, 1893.

of the geology of South Mountain, and has for many years invested it with a reputation for complexity which it in no way deserves.[1]

In Maryland and Virginia the acid and basic lavas and tuffs of South Mountain are extended southward as an important element in the composition of the Blue Ridge. They have been somewhat studied by the writer in this region and have been mapped and described by Keith.[2] This author mentions two quartz-porphyry areas showing flow-structure and tuffs, the larger between Catoctin and Blue mountains in Maryland, and the smaller near Front Royal in Virginia. He says that the diabase shows many indications of being a surface flow, and that it extends along the Blue Ridge from Maryland half way across Virginia, with an average width of twenty miles.

Southern States.—Volcanic rocks are largely developed in the central portion of both the Carolinas, as may be gathered from the old reports of Emmons and Lieber. During the past summer the writer had the opportunity of examining the belt in Chatham and Orange counties, North Carolina, in company with the State Geologist, Professor J. A. Holmes. The time at command was inadequate for the thorough exploration of the volcanic belt which skirts the western edge of the Triassic sandstone, but in a drive from Sanford to Chapel Hill an abundance of the most typical ancient lavas, mostly of the acid type, was encountered. On the road from Sanford to Pittsboro purple felsites and porphyries showing spherulites and beautiful flow-structures, and accompanied by pyroclastic breccias and tuffs, were met with two miles north of Deep river and were almost continuously exposed to Rocky river. Here devitrified acid glasses with chains of spherulites and eutaxitic structure were collected, while beyond as far as Bynum on Haw river, four miles northeast of

[1] See J. P. LESLEY: Summary Final Report, Penn. Geol. Survey, Vol. 1, p. 151, 1892.

[2] American Geologist, Vol. 10, pp. 366–68, December, 1892. Geologic Atlas of the U. S., Harper's Ferry Sheet (*in press*). For their distribution in Maryland see the Geological Map of the State, edited by G. H. WILLIAMS, and published in the World's Fair Book "Maryland," Baltimore, 1893.

Pittsboro, the only rocks seen were of the same general character. On the farm of Spence Taylor, Esq., in Pittsboro, a bright red porphyry with flow lines is exposed in so altered a condition that it can be easily cut into any form with a knife, though it still preserves all the details of its structure. It looks not unlike the well known pipe-stone, or Catlinite of Minnesota. Three quarters of a mile beyond Pittsboro on the Bynum road there is a considerable exposure of a basic amygdaloid. South of Hackney's Cross Roads there are other excellent exposures of the ancient rhyolites with finely developed spherulitic and flow-structures. Numerous specimens were here collected which place the character of these rocks as surface flows beyond a doubt. Another locality in the volcanic belt was visited on Morgan's Run, about two miles south of Chapel Hill. Here are to be seen admirable exposures of volcanic flows and breccias with finer tuff deposits, which have been extensively sheared into slates by dynamic agency. Toward the east and north these rocks pass under the transgression of Newark sandstone. The accompanying sketch-map (Fig. 2) shows the relations of the above mentioned localities in Chatham and Orange counties, N. C. From still another locality at the cross-road near the northern boundary of Chatham county, fifteen miles southwest of Chapel Hill, Professor Holmes informs me specimens of undoubted volcanic rocks have recently been secured; he has also sent to me within the past month a suite of similar specimens from Pace's Bridge on Haw river, three miles above Bynum.

In his upper division of the Taconic System in North Carolina, Emmons describes numerous beds of "chert or hornstone" intercalated in the slates and sometimes forming isolated bosses, whose origin he is at a loss to account for. He says they are not metamorphic, but does not suggest for them an igneous origin.[1] The hypothesis that these rocks may also be of volcanic origin is sustained by Emmons' description of "brecciated conglomerates" associated with the chert beds, which are composed

[1] Geological Report of the Midland Counties, N. C., 1856, pp. 66-68.

of an argillaceous or chloritic base, containing angular chert fragments of all sizes up to two feet. He mentions many localities

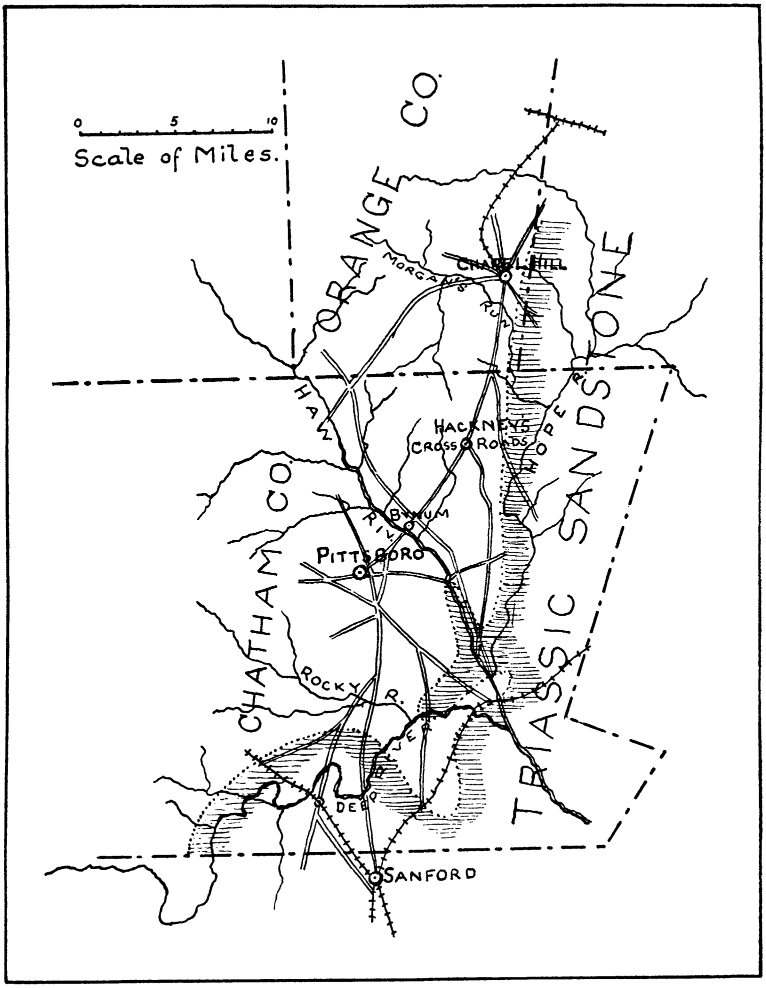

FIG. 2.

FIG. 2. Sketch map of parts of Chatham and Orange counties, N. C., showing localities for ancient volcanic rocks.

for these rocks, most of which are near the Yadkin river in Davidson, Rowan and Montgomery counties.

I am informed by Mr. Arthur Keith that he discovered a

large area of quartz-porphyry in the Great Smoky Mountains in Yancey Co., N. C., during the past summer.

The geological reports on South Carolina, by Lieber, describe a great development of igneous rocks which cross the state in the continuation of the North Carolina volcanic belt and which are themselves very probably in part of surface origin. His first report for 1856, which treats of Chesterfield, Lancaster, Chester and York counties, mentions among other more coarsely granular igneous rocks, eurite or quartz-porphyry, aphanitic-porphyry and melaphyre.[1] The counties of Union and Spartanburg, dealt with in Lieber's second report, are much poorer in igneous rocks, though he here adds the types schistose aphanite and minette. On the geological map of South Carolina, published by the Department of Agriculture in 1883, the belt of aphanitic greenstones and porphyries is shown to be continuous across the state in a southwest direction, and the statement is made that the greenstones predominate toward the north, and the porphyries toward the south, in Abbeville county.

Upon an expedition undertaken at the instigation of the writer, Prof. S. L. Powell of Newbury, S. C., found at Chester abundant eruptive rocks (granites and diorites), but none of unmistakably volcanic origin. At Lancaster, on the other hand, he found amygdaloids and felsites, showing distinct flow-structures which are certainly of igneous origin and could only have solidified at the surface.

In Georgia and Alabama nothing can be stated with certainty in regard to ancient volcanic rocks as the crystalline portions of these states have not as yet been petrographically investigated. The porphyry area of Abbeville county, S. C., is probably continued into Georgia. One single specimen of quartz-porphyry showing a beautiful micropoikilitic structure, collected in northwestern Georgia near the Tennessee line, has already been mentioned by the writer.[1] A box of specimens kindly sent

[1] Report on the Survey of South Carolina for 1856, 2d ed., Columbia, 1858, p. 31. Lieber had the German ideas regarding igneous rocks and their nomenclature. His "trachyte," "domite" and "phonolite" are probably fine grained varieties of the acid volcanic types.

to me for examination by Professor Eugene Smith of Alabama, proved to contain nothing which could be identified as ancient volcanic material.

GENERAL CONCLUSIONS.

The above rapid survey of the now known and probable areas of ancient volcanic rocks in the crystalline portion of the Appalachian system reveals the fact that this class of material is both abundant and widely distributed. From Newfoundland to Georgia it has been identified. For many areas the evidence of surface or volcanic origin is conclusive, while in many others it is as yet only probable.

The areas of these ancient volcanic rocks now known fall roughly in two parallel belts (see map); of these the eastern embraces the exposures of Newfoundland, Cape Breton, Nova Scotia, the Bay of Fundy, Coast of Maine, Boston basin and the central Carolinas; while the western belt crosses the Eastern Townships and follows the Blue Ridge through southern Pennsylvania, Maryland, Virginia, North Carolina to Georgia.

The purpose of the present communication will be accomplished if it succeeds in directing attention to this group of rocks. New areas should be added; probable areas investigated; and known areas monographed all along this old mountain range. How fruitful a field is here spread out to students of geology and petrography may be seen from the results of work in analogous regions by Harker[2] and Mügge.[3]

The identification of truly volcanic rocks in highly or partly crystalline terrains possesses far more than a petrographical significance, since by fixing what was the surface at the time of their formation, they furnish a certain datum for tracing out the sequence of later geographic changes and geological development.

GEORGE HUNTINGTON WILLIAMS.

[1] Am. Jour. of Science (3d ser.) Vol. 46, p. 47, July, 1893; and this Journal, Vol. I, p. 179, 1893.

[2] The Bala Volcanic Series of Caernarvonshire, Sedgwick prize essay for 1888, by A. HARKER, Cambridge, 1889.

[3] Untersuchungen über die "Lenneporphyre" in Westfalen und den angrenzenden Gebieten by O. MÜGGE. Neues Jahrbuch für Min., etc., Beilage Band viii., pp. 525–721, 1893.